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REMOTE TRACK SWITCH POSITION INDICATION SYSTEM

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REMOTE TRACK SWITCH POSITION INDICATION SYSTEM

by

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University of New Brunswick
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Since some of the accepted measures in the industry are imperial, metric measures are not always used in this report.

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16. Abstract

There are approximately 6000 railway track switches in non-signalled territory across Canada, many of which are potentially obscured or susceptible to tampering. The unintended diversion of a train by an improperly lined switch could potentially result in substantial human and material loss.

This report summarizes the identification, testing, and evaluation of a remote track switch position indication system for potential use in non-signalled territory. An extensive search of suppliers across North America and Europe identified Global Rail Systems as being able to supply a low-cost prototype system capable of providing advance warning of switch position in non-signalled territory.

The system was tested for its ability to accurately determine switch position and consistently provide advance warning to locomotive engineers. Nearly all (98%) of the audio queries returned the correct switch position without any difficulties. The remaining 2 percent did not return an audio response to the operators. In all instances where the switch position was successfully communicated by digital audio message, the corresponding correct LED visual indication was displayed on site.

Results showed that the system was effective at indicating both a visual (LED lights) and audio indication of switch position when queried by the locomotive engineers.

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16. Résumé

Il existe environ 6000 aiguilles ferroviaires en zone exempte de signalisation au Canada, dont beaucoup peuvent être cachées ou sujettes au sabotage. Le déroutement non intentionnel d'un train par une aiguille mal orientée peut entraîner des pertes de vie et des pertes matérielles importantes.

Ce rapport résume les travaux de repérage, d'essai et d'évaluation d'un téléindicateur de position d'aiguille pour utilisation en zone exempte de signalisation. Au terme d'une vaste recherche à l'échelle de l'Amérique du Nord et de l'Europe, il a été déterminé que Global Rail Systems était en mesure de fournir un prototype peu coûteux capable de donner un avertissement avancé de la position d'une aiguille en zone exempte de signalisation.

Les essais visaient à déterminer la capacité du système de déterminer avec exactitude la position de l'aiguille et de donner de façon constante un avertissement avancé aux mécaniciens de locomotive. Presque toutes (98 %) les interrogations par radio ont reçu une réponse sonore indiquant la position exacte de l'aiguille, sans difficulté. Aux 2 % d'interrogations restantes, les mécaniciens n'ont reçu aucune réponse sonore. Dans tous les cas où le signal numérique indiquait la position exacte de l'aiguille, les DEL sur place affichaient un signal visuel conforme.

Les résultats ont révélé que le système pouvait répondre correctement aux interrogations des mécaniciens de locomotive, autant par un signal visuel (feux à DEL) que par un signal sonore de la position de l'aiguille.

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    - Charles Roberts
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    - Karen Robichaud

EXECUTIVE SUMMARY

There are approximately 6000 railway track switches in non-signalled territory across Canada, many of which are potentially obscured or susceptible to tampering. The unintended diversion of a train by an improperly lined switch could potentially result in substantial human and material loss.

The objective of this project was to identify, test, and evaluate a remote railway track switch position indication system for potential use in non-signalled territory. The project was carried out by the University of New Brunswick Transportation Group in partnership with the New Brunswick Department of Transportation, NB Southern Railway, Global Rail Systems, and the Transportation Development Centre and ITS Office of Transport Canada. An extensive search of suppliers across North America and Europe identified Global Rail Systems as being able to supply a low-cost prototype system capable of providing advance warning of switch position in non-signalled territory.

Testing took place on an NB Southern Switch located in Westfield, New Brunswick. The system was tested for its ability to accurately determine switch position and consistently provide advance warning to locomotive engineers. There were 341 (trains and Hi-Rails) observations made by engineers between May 2005 and March 2007. Nearly all (98%) of the audio queries returned the correct switch position without any difficulties. The remaining two percent did not return an audio response to the operators. There were four instances in which the system required a second or third radio query to obtain a system response. In all instances where the switch position was successfully communicated by digital audio message, the corresponding correct LED visual indication was displayed on site.

Observation logs indicated that LED lights were visible under a variety of weather conditions. Among the 341 recorded observations, 99 percent were classified as good

visibility and 1% were classified as fair visibility. There were no observations classified as poor visibility.

Results showed that the system was effective at indicating both a visual (LED lights) and audio indication of switch position when queried by the locomotive engineers.

SOMMAIRE

Il existe environ 6000 aiguilles ferroviaires en zone exempte de signalisation au Canada, dont beaucoup peuvent être cachées ou sujettes au sabotage. Le déroutement non intentionnel d'un train par une aiguille mal orientée peut entraîner des pertes de vie et des pertes matérielles importantes.

Ce projet avait pour objectif de repérer, mettre à l'essai et évaluer un téléindicateur de position d'aiguille en vue d'une utilisation possible en zone exempte de signalisation. Le projet a été réalisé par le Groupe des transports de l'Université du Nouveau-Brunswick, en partenariat avec le ministère des Transports du Nouveau-Brunswick, la NB Southern Railway, Global Rail Systems, et le Centre de développement des transports et le Bureau des STI de Transports Canada. Au terme d'une vaste recherche à l'échelle de l'Amérique du Nord et de l'Europe, il a été déterminé que Global Rail Systems était en mesure de fournir un prototype peu coûteux capable de donner un avertissement avancé de la position d'une aiguille en zone exempte de signalisation.

Les essais ont porté sur une aiguille de la NB Southern située à Westfield, au Nouveau-Brunswick. Ils visaient à déterminer la capacité du système de déterminer avec exactitude la position de l'aiguille et de donner de façon constante un avertissement avancé aux mécaniciens de locomotive. De mai 2005 à mars 2007, 341 observations (trains et engins rail-route) ont été faites par des mécaniciens. Presque toutes (98 %) les interrogations par radio ont reçu une réponse sonore indiquant la position exacte de l'aiguille, sans difficulté. Aux 2 % d'interrogations restantes, les mécaniciens n'ont reçu aucune réponse sonore. Dans quatre cas, il a fallu envoyer une deuxième ou une troisième interrogation radio avant d'obtenir une réponse. Dans tous les cas où le signal numérique indiquait la position exacte de l'aiguille, les DEL sur place affichaient un signal visuel conforme.

Les carnets d'observation ont indiqué que les feux à DEL demeuraient visibles dans des conditions météorologiques variées. Des 341 observations enregistrées, 99 % faisaient

état d'une bonne visibilité et 1 %, d'une visibilité acceptable. Aucune observation n'a classé la visibilité dans la catégorie mauvaise.

Les résultats ont révélé que le système pouvait répondre correctement aux interrogations des mécaniciens de locomotive, autant par un signal visuel (feux à DEL) que par un signal sonore de la position de l'aiguille.

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LIST OF SYMBOLS, NOMENCLATURE AND ABBREVIATIONS

BNSF	Burlington Northern Santa Fe
CAD	Canadian Dollars
CAMBS	Computer Assisted Manual Block System
CTC	Centralized Traffic Control
CN	Canadian National Railway
CPR	Canadian Pacific Railway
CROR	Canadian Railway Operating Rules
FRA	Federal Railway Administration (U.S.)
GERX	Gershaw Recycling Company
GBO	General Bulletin Order
ITS	Intelligent Transportation Systems
LED	Light Emitting Diode
MBS	Manual Block System
NBDoT	New Brunswick Department of Transportation
NTSB	National Transportation Safety Board (U.S.)
OCS	Occupancy Control System
UNB	University of New Brunswick
RTC	Rail Traffic Control
TDC	Transportation Development Centre
TSB	Transportation Safety Board of Canada
USD	United States Dollars
UP	Union Pacific

m	metres
mph	miles per hour
km/h	kilometres per hour
sec	seconds

1.0 INTRODUCTION

This study evaluated a low-cost device for indicating switch position along non-signalled sections of railway lines. The evaluation was carried out by the University of New Brunswick's (UNB) Transportation Group in partnership with the New Brunswick Department of Transportation (NBDoT), NB Southern Rail, Global Rail Systems, and the Transportation Development Centre (TDC) and ITS Office of Transport Canada.

Non-signalled territories do not have advance signals to indicate position of hand-operated switches. Across Canada, such areas have been host to multiple collisions and numerous encounters of misaligned switches. Computer-aided or automated control switches are available and are frequently used all over Canada in Centralized Traffic Control (CTC) territory. However, such systems are typically used in high-traffic sections of track because their high cost prohibits them from being used in low-traffic areas. Currently, low-cost alternatives to these systems remain in the development stage.

1.1 Problem Statement

The Railway Association of Canada has identified approximately 6000 switches on 14,000 miles of railway lines across Canada. Further data show that there are 3500 switches on Canadian National Railway (CN) track and 2000 on Canadian Pacific Railway (CPR) track located in non-signalled territory (Railway Association of Canada, 2004). Nationally, there are on average 10 occurrences of trains unexpectedly encountering reversed mainline switches in non-signalled territory annually (TSB, 2004). Although this number appears low, the significance of a collision involving improperly lined switches and the potential for substantial loss have made them an area of interest for Transport Canada.

The potential obscurity of these switches and their susceptibility to tampering has created a need for a reliable, low-cost warning system. Such a system would reduce the

probability of an often high-consequence event by providing adequate warning of switch position to train crews operating in non-signalled territory.

1.2 Background

This study was completed under the Rural ITS Research Program at UNB. The goal of the program is to evaluate the effectiveness of unproven ITS technologies to provide a solution to transportation-related safety issues in rural areas of Canada. It was established under the UNB's Transportation Group through a contribution agreement between Transport Canada and NBDoT. Funding was provided under the Strategic Highway Infrastructure Program (SHIP).

Funding for the overall research program was available from September 2004 until September 2006. NB Southern Railway agreed to partner with the Transportation Group for the two rail projects by providing test sites, personnel, and expertise in developing the work plan. Following the expiration of the original study period, TDC agreed to fund an extension to the project in order that an additional winter period could be included in the observations. This enabled testing to extend through until March 2007.

1.3 ITS Architecture for Canada

The Intelligent Transportation Systems (ITS) Architecture for Canada (ITS Architecture for Canada, 2004) was developed to provide a common framework for planning, defining, and integrating ITS. It represents the contributions of the wide spectrum that is the ITS community, including transportation practitioners, systems engineers, system developers, consultants, etc. The architecture defines:

- The functions (e.g., gather traffic information or request a route) that are required for ITS.

- The physical entities or subsystems where these functions reside (e.g., the roadside or the vehicle).
- The information flows that connect these functions and physical subsystems together into an integrated system.

The ITS Architecture for Canada is composed of a series of user services and sub-services. User services represent what the ITS system should do from the users' perspectives while user sub-services are focused on context and refined definition. A series of hierarchical requirements accompany each user sub-service and are essential to providing the final ITS service.

A switch position indicator for non-signalled territory does not fall within any specific user service or sub-service of the ITS Architecture for Canada. This does not, however, imply that a switch position indicator should not be classified as an ITS technology. Transport Canada defines ITS as a

> *broad range of diverse technologies applied to transportation to make systems safer, more efficient, more reliable and more environmentally friendly.... The range of technologies involved includes sensor and control technologies, communications, and computer informatics and cuts across disciplines such as transportation, engineering, telecommunications, computer science, finance, electronic commerce and automobile manufacturing. (Transport Canada, 2005a)*

Based on this definition, a switch position indicator would most appropriately be described as an ITS technology. Such a system would increase safety, improve efficiency, and use a variety of innovative and dynamic technologies.

1.4 Project Goals and Objectives

The goal of this project was to identify, test, and evaluate a low-cost track switch position indication system in non-signalled territory that would consequently improve the safety and efficiency of Canada's railways. Such a system should be highly reliable and easy to install, operate, and maintain. Specific objectives of the study designed to meet the overall goal included:

- establish a Technical Steering Committee of stakeholders,
- identify potential products that meet the criteria for the program and have not yet been used or tested in the Canadian environment,
- select the product with the highest probability for success for installation and testing,
- develop evaluation criteria and performance thresholds,
- select a test site and install the equipment,
- collect data and analyze results,
- evaluate the product for use in Canada, and
- prepare a report.

1.5 Scope

The funding available under the Rural ITS Research Program restricted the scope of the study to an observation period from May 2005 until September 2006. Additional funding from TDC extended the study until March 2007. Although project funding became available in September 2004, it took several months to identify a supplier as well as acquire and install the equipment. Study sites were located in New Brunswick because of NBDoT's role in the program and to allow access by UNB Transportation Group researchers. Funding for equipment acquisition and data collection efforts limited the number of products tested to one. Efforts were made to select a test site that would be

representative of rural conditions in other parts of the country. Equipment selection was limited to products that were already developed and could be implemented immediately.

2.0 TRAIN CONTROL

The movement of trains is governed by the actual train control system in place. These systems ensure separation of trains moving in the same direction and allow the safe passing of trains moving in opposite directions. The process of train control is carried out by a number of elements, either manual or automatic, located on the train, along the track, in stations and at remote facilities. These elements work together to achieve four major functions:

1. Train Operations: Control of train movement and stopping at stations.
2. Train Protection: Prevention of collisions and derailments.
3. Train Supervision: Direction of train movement in relation to schedule.
4. Communication: Interchange of information among the elements of the system. (United States Congress, 1976)

Three methods of train traffic control are used in Canada today. These include Centralized Traffic Control (CTC), Occupancy Control System (OCS), and Special Control System (TSB, 1999). Train operations on federally regulated railways are governed by the Canadian Rail Operating Rules (CROR).

2.1 Centralized Traffic Control (CTC)

CTC systems have been used for a number of years in Canada, typically in high-traffic areas. A series of track circuits identifies which sections of main track, signalled sidings, and signalled yard tracks are occupied. When track circuits are de-activated in the presence of a train, an indication is sent to the Rail Traffic Controller (RTC) as well as to wayside signals visible to train crews. The train control signals are known as block signals, where a block is defined in part by the CROR as "A length of track of defined limits, the use of which by a train or engine is governed by block signals..." (Transport Canada, 2005b).

The RTC can request a route and signal in the system to provide a permissive or stop signal. The RTC also has the ability to control all "dual" (equipped for both power and manual operation) and "power" (equipped for power operation but not manual operation) operated switches (TSB, 1999). They are, however, unable to control any hand-operated switches. The power or dual control switches are found in areas known as controlled locations. Intermediate block signals (not controlled by RTC) govern the movement of trains between controlled locations. The system provides train crews with advance warning of the conditions that lie ahead on at least one block. However, crews must anticipate the following signals to be more restrictive. CTC is the safest form of train control and provides the greatest efficiency by effectively reducing the headways between consecutive trains.

2.2 Occupancy Control System (OCS)

Before 1990, Manual Block System (MBS) rules were used as a method of train control in areas of low-density track. In a manual block system, trains are tracked manually by an RTC to ensure safe operations. The RTC issues and records track authorities on paper. Near the end of the 1980s, CN and CPR created separate versions of computer-assisted MBS (CAMBS). The CAMBS version improved the MBS by using an electronic database to record information. A series of procedures for system operation followed. These procedures were revised and adopted as the OCS rules under CROR. The intention of the OCS rules is to prevent conflicting track authorities and promote accurate communication and data entry through the requirement to repeat information, make written records and provide acknowledgement of accuracy (TSB, 1999).

Two-way radio is the primary source of communication of track authority from the RTC to crews within OCS. Information received by train crews is added to a written record and repeated back to the RTC for verification. Operating rules require the information to

be entered and generated by the OCS computer systems at the same time as the crews write it.

2.3 Train Control in Non-signalled Territory

Switches in non-signalled territories are hand-operated, and the movement of trains on such tracks is supervised by RTCs who, by radio or other means of communications, issue operating authorities and instructions to the train crews as may be required (Transport Canada, 2001). In Canada, there are over 1200 miles of non-signalled territory in which passenger trains operate. Approximately 360 miles of track in New Brunswick are found in non-signalled territory.

CROR Rule 104 (Transport Canada, 2005b), which applies to all territories, outlines approved procedures for the operation of main track hand-operated switches. The following describes key sections of CROR Rule 104 for hand-operated switches:

a. … the normal position for a main track switch is for main track movement. Except as provided in paragraph (b), main track switches must be lined and locked in normal position. A main track hand operated switch must display a reflectorized target, or light and target, to indicate the following: Green: normal position; Red: reversed position.

b. A main track switch may be left in the reverse position when;
   1) Directed by General Bulletin Order(s) (GBO), clearance or special instructions, and protection has been provided against all affected trains or engines,
   2) Attended by an employee, who must be in position to restore the switch to normal before it is occupied by an approaching train or engine on the main track,
   3) Occupied by equipment,

4) Required in the application of Rule 40.2,
5) In OCS or cautionary limits;
   i. Equipment is left on the main track,
   ii. The equipment is left as close as practical to the switch, and
   iii. Movement over the same switch is required when returning to such equipment,
6) In CTC, equipment is left within the same controlled block. When this cannot be done, RTC permission must be obtained.

c. Unless otherwise specified by special instructions, switches other than main track switches, when equipped with a lock, must be lined in normal position and locked after having been used.

d. The employee handling a main track hand operated switch in non-signalled territory must, from the location of the switch, communicate with another rules qualified employee to confirm the position in which the switch has been left, lined and locked. The employee receiving this report must repeat it back to the employee who handled the switch. Communication may be achieved by personal contact, radio or telephone.

q. Unless or until the switch is seen to be in normal position, trains and engines approaching a main track hand operated switch in a facing point direction in OCS territory, unless otherwise governed by signal indication, must not exceed the following speeds from one-quarter of a mile of the switch:

- PASSENGER 50 MPH
- FREIGHT 45 MPH
- FREIGHT handling Special Dangerous Commodities 40 MPH

A main track switch may only be handled by those employees who have passed the required examination in the Canadian Rail Operating Rules and are in possession of a valid certificate of rules qualification.

3.0 SWITCHING TECHNOLOGY

3.1 Switching Basics

The path of a train is defined by the tracks it follows. There is often a need, however, to choose an alternative route or move to a siding to allow another train to pass. In order for these movements to occur, a turnout must be present. The transfer of the train from one track to another is accomplished through the use of movable rails known as points (Calvert, 2004a). Turnouts are described by their orientation in relation to the normal direction of travel over the line in which they are situated. A *facing point* (Arrow A, Figure 3.1) turnout indicates that a train would be travelling in a direction facing the points (diverging tracks). A *trailing point* (Arrow B, Figure 3.1) turnout, on the other hand, is approached from the opposite direction (converging tracks) (Calvert, 2004b). In other words, the facing point direction is that in which there is a choice of routes.

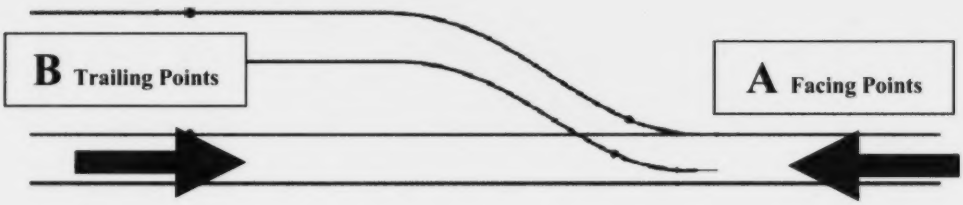

Figure 3.1 - Facing and Trailing Points' Directions

A turnout is composed of two parts. The first, referred to as the crossing, allows the movement of the flanged wheel from one track to another. Guard rails press against the back of the opposite wheels to prevent the flange from slipping and striking the crossing points (Calvert, 2004b).

The switch is the second component of the turnout and is used to select the actual route. Switches are controlled either manually or automatically by machine. In the manual operation, a lever located on a switch stand converts a rotary motion about a horizontal or vertical axis to a linear motion, moving the switch rails by means of the operating rod. An automatic switch instead uses some form of a machine to move the points into the proper position. The switch usually includes two targets; one displaying red for the reversed position and one displaying green for the normal position.

3.2 Current Switching Technology

The basics of switches have remained relatively unchanged over the years. Today, the major distinction is made between manual switch stands and machine-operated switches. In recent years, changes in configuration, ergonomics, and appearance have made both products easier to install, operate, and maintain. Although switch machines are favoured, manual switches are still used quite regularly, especially in non-signalled-territory where their lower cost and lack of power requirement make them a more appropriate choice. There are three basics means of controlling the position of a switch:

Hand-Operated Switches

Hand-operated switch stands, as seen in Figure 3.2, were once the standard in railway switching and are still used regularly today. These stands require the manual movement of a lever when varying movements are required. When the lever is operated, the switch target is turned to indicate the position of the switch. Standard protocol requires that the switch be left locked in the normal position.

Figure 3.2 – Hand-Operated Switch
[source: TSB, 2001]

Semi-Automatic Switches

A semi-automatic switch stand protects against derailments and damage to a switch or a switch stand when switches are trailed through. It permits a trailing movement without slowing or stopping the train for the hand operation of switch stands. As the first pair of wheels forces the switch points beyond the half-thrown position, the two double coil springs inside the stand snap the switch points completely over, allowing the train to pass safely through the switch. The switch points must be manually returned to the normal position. These switches are used in railway yards.

Power-Operated or Dual Control Switches

Switch machines are power-operated versions of the manual switch. Switch machines come in various configurations and can be powered by a permanent power source or batteries. These machines can be controlled from a remote location such as an RTC office.

Further differentiation between switches can be made regarding the manner in which trains are alerted of switch position. The most commonly used method of notification is the use of red and green mechanical targets. The reflectorized targets provide the least amount of advance warning. Their visual range is limited and their ability to be seen is

significantly affected by prevailing weather conditions and the condition of the targets. Train control signals that can communicate speed at which trains should proceed are much more effective but impose substantially greater costs.

Costs vary significantly among manufacturers and more so with type of switching mechanism. A manual switch stand with connecting rod, target and mast will typically cost around CAD$750 to $1300. Switch machines are far more expensive. Costs for these machines can range anywhere from USD$5000 to $30,000. All have varying features but perform the same task (Fiorio, 2005).

4.0 SWITCHING ACCIDENT HISTORY

4.1 Canada

In 2004 there were 12 reported incidents of trains encountering main track switches in abnormal position. Since 1994, there have been more than 140 such occurrences. The number of cases for each of those years is shown in Table 4.1.

Table 4.1 - Manually Operated Switch Encountered in Abnormal Position

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
No. Occurrences	24	15	8	12	14	15	17	9	9	11	12

[Source: TSB, 2004]

In recent years there have been a number of serious collisions involving manually operated switches in Canada. Many of these collisions have resulted in personal injury or loss of life, and almost all incurred significant property damage. Three examples typical of these incidents are summarized below.

4.1.1 Rockwood, Ontario, July 9, 2000

On July 9, 2000, a VIA Rail Canada Inc. passenger train was unintentionally diverted into a siding, colliding with unattended track machines. The collision resulted in the derailment of the locomotive and two coaches; however, all track equipment remained upright. The red switch target, showing that the switch was lined in reverse, was partially obscured by shrubs growing on the right-of-way.

Twelve passengers and two employees sustained minor injuries. Approximately 200 L of petroleum products from ruptured fuel tanks, hydraulic systems, and lubricating

reservoirs was lost to the environment. Approximately 120 m of main track sustained substantial damage. Four machines were destroyed and several were heavily damaged (TSB, 2000a).

4.1.2 Miramichi, New Brunswick, January 30, 2000

A VIA Rail Canada Inc. passenger train, proceeding eastward at the Newcastle Subdivision on the New Brunswick East Coast Railway, was diverted from the main track by a crossover switch that was lined and locked in the reverse position. The train entered the adjacent yard track at a speed of 29 mph and collided with 11 stationary cars. Both locomotives and 7 of the 10 passenger cars derailed. Of the 127 people on board, 43 were transported to hospital.

The train was travelling approximately 41 mph and was only 330 ft. from the switch when the locomotive engineer recognized it was in the reverse position. The switch target was found to be in poor condition, well below standard, making it much more difficult to determine switch position (TSB, 2000b).

4.1.3 Thamesville, Ontario, April 23, 1999

A VIA Rail Canada Inc. train, travelling eastward on the north main track of the CN Chatham Subdivision, at Thamesville, Ontario, encountered a reversed switch, crossed over to another track and derailed. The derailed train collided with stationary rail cars loaded with ammonium nitrate. Over 300 tons of ammonium nitrate was spilt over the crash site. Maximum permissible speed for passenger trains travelling eastward on the north track was 80 mph.

All four passenger cars and the locomotive were derailed as well as four of the stationary cars on the adjacent yard track. The two crew members in the locomotive were fatally injured. Seventy-seven of the 186 passengers and crew on board were treated at hospital.

Approximately 150 m of track was destroyed. The locomotive was damaged beyond repair and the leading two passenger cars sustained substantial damage (TSB, 1999).

4.2 United States

Forty percent of railroad track in the United States is in territory that does not have signals. Federal Railway Administration (FRA) data indicate that 23 train collisions were caused by improperly aligned switches during the first nine months of 2004, out of 2577 total incidents on such track. Many of these collisions have resulted in significant property damage, personal injury, and even loss of life. The following sections briefly outline a few of the collisions that have occurred in the United States.

4.2.1 Graniteville, South Carolina, January 6, 2005

A Norfolk Southern freight train with two locomotives and 42 rail cars struck a locomotive with two rail cars parked at a siding at Avondale Mills. Three cars on the moving train were carrying 90 tons of chlorine that was released in the collision. One of the loose cars struck a tree, knocked it onto a car and trapped a woman inside for about two hours; the woman was removed and taken to a hospital for treatment. Nine people were killed in the collision and more than 350 were sent to the hospital for treatment, most from inhalation of the chlorine gas. About 5000 people within a one-mile radius of the crash were evacuated.

The FRA attributed the collision to a hand-operated switch left in the reversed position. Crew members operating a train on the night before the collision were to move their train into a siding and then return the switch to the normal position. The switch remained improperly aligned, allowing the other train to enter the siding and collide with the parked train (CNN, 2005).

4.2.2 Bieber, California, January 8, 2005

A freight train comprising 7 locomotives and 14 cars was derailed, resulting in the injury of two workers and over USD$970,000 in damages. The train was unexpectedly diverted onto an industrial track, where it struck two rail cars, after the switch was left improperly lined (Brotherhood of Locomotive Engineers and Trainmen, 2005).

4.2.3 Branson, Missouri, May 14, 1997

A Missouri and Northern Arkansas Railroad (M&NA) train travelling in non-signalled territory was inadvertently sent onto a siding track where it collided with another train. The lead locomotive of the diverted train caught fire upon impact; both locomotives of the stationary train were derailed. The two crew members sustained minor injuries in the collision. The collision resulted in over USD$400,000 dollars in damages.

Prior to the collision, the M&NA train was travelling at a speed of 26 mph as it proceeded around a sharp left hand curve. When the train rounded the turn, crew members noticed the switch lined for the siding and applied the emergency brake. The train failed to stop in time and collided with the stationary train (National Transportation Safety Board, 1998a).

4.2.4 Gainesville, Virginia, May 2, 1997

A Norfolk Southern Freight Train No. 214 was derailed when it traversed a hand-operated switch in the reverse position. Three locomotives and seven cars left the track in the accident. No injuries were reported; however, approximately 2500 gal. of diesel fuel and 100 gal. of flammable liquid were dispersed from the train. A building adjacent to the

track was extensively damaged after it was struck by a piece of rail equipment. In total, damages were estimated to be USD$650,000.

Two hours before the accident occurred, two other train movements had occurred at the same switch. Following the movements, yard crews failed to return the switch to its normal main line position. Train No. 214 proceeded to cross over the misaligned switch and was subsequently derailed (National Transportation Safety Board, 1998b).

4.3 Safety Action Taken

4.3.1 Canada

(TSB, 2000a)

In response to an increase in the mishandling of main track switches, Transport Canada issued a Notice and Order on July 14, 2000, in accordance with the *Railway Safety Act*, that outlined procedures to be followed to reduce the risk of main-track switches in OCS territory being left in the reverse position. The order required two CROR-qualified employees to confirm, in person, that the switches have been properly positioned after handling. Furthermore, employees responsible for the handling of switches were to be given training on the application of CROR Rule 104 within 60 days and annually thereafter.

On November 14, 2000, Transport Canada, believing that industry resolutions were not sufficient, issued an Emergency Directive to VIA, CN, CPR and GERX. The directive included speed restrictions for trains approaching a facing-point switch in non-signalled territory until position is confirmed and there is confirmation between rules-qualified employees that the switch is properly lined. On May 14, 2001, Transport Canada extended the Directive for a further six months and ordered railways to revise CROR Rule 104 and submit their proposals within 150 days.

On December 1, 2001, the revised CROR Rule 104 went into effect. The revisions include following:

> *(d) The employee handling a main track hand operated switch in non-signalled territory must, from the location of the switch, communicate with another rules qualified employee to confirm the position in which the switch has been left, lined and locked. The employee receiving this report must repeat it back to the employee who handled the switch. Communication may be achieved by personal contact, radio or telephone.*
>
> *(q) Unless or until the switch is seen to be in normal position, trains and engines approaching a main track hand operated switch in a facing point direction in OCS territory, unless otherwise governed by signal indication, must not exceed the following speeds from one-quarter of a mile of the switch;*
>
> *PASSENGER – 50 MPH*
> *FREIGHT – 45 MPH*
> *FREIGHT handling Special Dangerous Commodities – 40 MPH*

4.3.2 United States

Following two serious switching-related collisions in January 2005, the Federal Railroad Administration issued a Notice of Safety Advisory regarding the position of switches in non-signalled territory. The Safety Advisory was to advise all railroads to review operating rules and take action to ensure train crews operating main track switches in non-signalled territory return switches to their normal position following their use.

The FRA's regulations require that railroad employees be instructed on the meaning and application of operating rules, and that they complete periodic testing to determine their level of compliance. Some railroads have already made changes to their operating rules to

address the issue of switches being left misaligned. In response to a collision involving a misaligned switch in Thomaston, Texas, Union Pacific Railroad Company (UP) implemented a new requirement on October 1, 2004, regarding non-signalled switches. Before reporting clear of the limits of a track warrant, the crewmember who is releasing the warrant must advise the train dispatcher that the switch has been restored to its normal position. If the crewmember fails to report this information, the train dispatching system prompts the dispatcher to request this information (Federal Railroad Administration, 2005).

Burlington Northern and Santa Fe Railway Company (BNSF) has also amended its operating rules. On October 31, 2004, BNSF began requiring train crews to report the position of the main track switch to the dispatcher when releasing the limits of their track warrants. The dispatching system prevents a track warrant from being cleared until the dispatcher confirms the switch position through a job briefing with the crew (Federal Railroad Administration, 2005).

Specific recommendations in the Safety Advisory include:

1) ensuring that their operating rules contain a provision, similar to that established on BNSF and UP, requiring crews operating manual switches in non-signalled territory to report to the dispatcher that the main track switches have been restored to normal position, before reporting clear of the limits of main track authority.

2) requiring the conductor of a train crew operating in non-signalled territory to complete and sign a Switch Position Awareness Form. FRA recommends that the form be completed in ink and contain the train symbol, date, subdivision, conductor's and engineer's names, and a listing by name and location of each main track switch operated by any member of the crew. The listing should contain the switch location and name, the time the switch was reversed, the time

the switch was returned to normal position, and the initials of the conductor and the engineer.

3) Requiring that the original Switch Position Awareness Form be submitted to the designated railroad official(s) as directed following each trip.

4) requiring that railroad officers review the completed Awareness Forms for accuracy. The results of these reviews should be incorporated into the railroad's operational tests and inspections programs as required by 49 CFR 217.9.

5) ensuring immediate dissemination of guidance on these revised rules and procedures and of the necessary forms to all affected operating personnel.

The FRA is also investigating the need for further action, such as regulatory or supplementary advisories. FRA operating practice inspectors will be monitoring the degree to which railroads have complied with the measures outlined in the advisory. Information gathered from inspections will be used to make future decisions regarding operation in non-signalled territory (Federal Railroad Administration, 2005).

Following further investigation of the January 6, 2005, accident in Graniteville, South Carolina, the National Transportation Safety Board made additional safety recommendations to the Federal Railroad Administration. These recommendations, R-05-14 through 17 (National Transportation Safety Board, 2005), are as follows:

Safety Recommendation R-05-14

On main lines in non-signalled territory, railroads are required to install an automatically activated device, independent of the switch banner, that will, visually or electronically, compellingly capture the attention of employees involved with switch operations and clearly convey the status of the switch both in daylight and in darkness.

Safety Recommendation R-05-15

In non-signalled territory and in the absence of switch position indicator lights or other automated systems that provide train crews with advance notice of switch positions, railroads are required to operate those trains at speeds that will allow them to be safely stopped in advance of misaligned switches.

Safety Recommendation R-05-16

Railroads are required to implement operating measures, such as positioning tank cars toward the rear of trains and reducing speeds through populated areas, to minimize impact forces from accidents and reduce the vulnerability of tank cars transporting chlorine, anhydrous ammonia, and other liquefied gases designated as poisonous by inhalation.

Safety Recommendation R-05-17

Determine the most effective methods of providing emergency escape breathing apparatus for all crewmembers on freight trains carrying hazardous materials that would pose an inhalation hazard in the event of unintentional release, and then require railroads to provide these breathing apparatus to their crewmembers along with appropriate training.

5.0 RELEVANT STUDIES

5.1 Systems to Indicate the Position of a Hand-Operated Switch

In 2001, the Transportation Group at the University of New Brunswick completed a study to identify the existence and availability of technologies capable of indicating the position of hand-operated switches on non-signalled sections of rail lines. The Transportation Group had been retained by TDC on behalf of Transport Canada's Rail Safety Directorate, to conduct a comprehensive review of technologies by surveying universities, research and/or development centres, and suppliers/manufacturers of signalling equipment. Institutions and firms in Canada, the United States, Europe, and Australia were contacted. Visits and interviews were also conducted with several Canadian institutions, associations, and railways.

Ten technologies were identified as having the potential of being used as a system to identify switch position. Of these, five were selected as having the greatest likelihood of successful application. Technologies ranged from individual components that could be assembled to create a complete system to a prototype being tested by CN. Key attributes of a chosen system were identified as a high level of reliability, low cost, simplicity of installation and operation, minimal maintenance, and extended durability.

A preliminary benefit-cost analysis was carried out based on data, which was limited in some instances. Benefits included savings from a reduction in property damage, personal injuries, fatal collisions, and running times. Basing benefits solely on a reduction in property damage and human injuries proved that installation of such systems would not be justifiable. However, installation becomes economically viable, even when only 5 or 10 percent of the value of travel time for passenger and cargo operations is considered in the analysis (Wilson *et al.*, 2001).

6.0 RESEARCH METHODOLOGY

6.1 Test Site

The test site for the switch position indicator was located on NB Southern's line in Grand Bay – Westfield, New Brunswick. Grand Bay – Westfield is a suburb of Saint John just northwest of the city. The site location is shown in Figure 6.1.

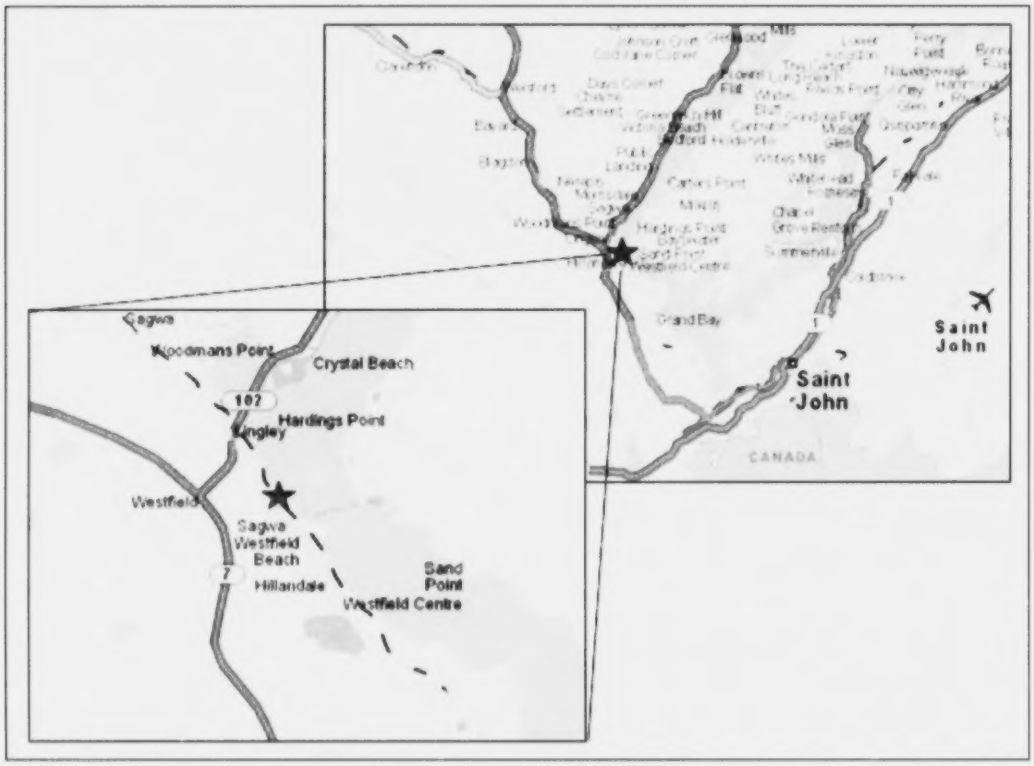

Figure 6.1 - Test Site Location

The site was chosen because:

- it was readily accessible for data collection,
- there was easy access for equipment installation,

- there was less chance of vandalism due to its location in a community and visibility from the adjacent highway, and
- it was near another piece of equipment being tested by UNB, allowing for more frequent site visits and synergies in data collection.

Due to the low traffic volume on the NB Southern line, use of switches is somewhat limited. Trains do no meet head on and thus there is no need for a train to pull into a siding to let another pass. To compensate for this, Hi-Rail vehicles, which travel the track daily, routinely queried the system and changed the position of the switch to ensure it was working properly.

6.2 Equipment Selection

Potential products were identified using existing contacts of the UNB Transportation Group and members of the Steering Committee, and through a literature review. These contacts included the Volpe National Transportation Systems Center and the Transportation Technology Center in the United States. Suppliers identified in a recent study by the UNB Transportation Group (Wilson *et al.*, 2001) were also contacted. Staff at Transport Canada's Transportation Development Centre assisted in the search by:

- providing a list of potential suppliers,
- preparing a brief article describing the research program for submission to transportation periodicals,
- providing a list of periodicals.

The resulting list of potential suppliers was reviewed and several were omitted because they had already been contacted or their products were not applicable. UNB prepared a brief description of the requirements for the switch indicator (see Appendix A) and e-mailed it to the remaining suppliers on the list. The suppliers were then contacted by

telephone. The requirements description was also sent to ITS Canada, which circulated it to its members as an industry opportunity.

Two potential suppliers were identified – Global Rail Systems and Solar Signals. Global Rail System's product, FAS-PAS, was selected for testing because it was felt to be in a more advanced stage of development and provided a more robust range of capabilities.

FAS-PAS, which stands for Fail Safe Audible Signal Power Activated Switch, provides visual and auditory indications of switch position. The system detects the position of the switch and relays this information to train crews via a two-aspect signal head. The signal displays a green colour when the switch is aligned in the normal position and a red colour when in the reversed position. Train engineers can also use the standard locomotive radio to query the switch and receive an auditory indication of its position. If the switch changes position following the initial query, the system will automatically provide an audible warning to the train engineer. The simplicity of the system, inclusion of fail-safe features, relatively low cost, and the fact that the system has not been tested in a harsh climate were the main reasons for choosing the FAS-PAS system. The system can be viewed in Figure 6.2. Major system components are listed in Table 6.1. A more detailed description of the system is provided in Appendix B.

Table 6.1 - Major Components of FAS-PAS System

• Track Circuits • 1 Switch Circuit Controller • 1 Global Logic Controller • 4 LED beacons (2 red; 2 green) with housings, visors, mounts, and wiring harnesses	• 2 solar panels and mounts • 1 – 120 amp battery • 1 – 15 ft. mast with ladder and platform • 1 aluminium case and foundation

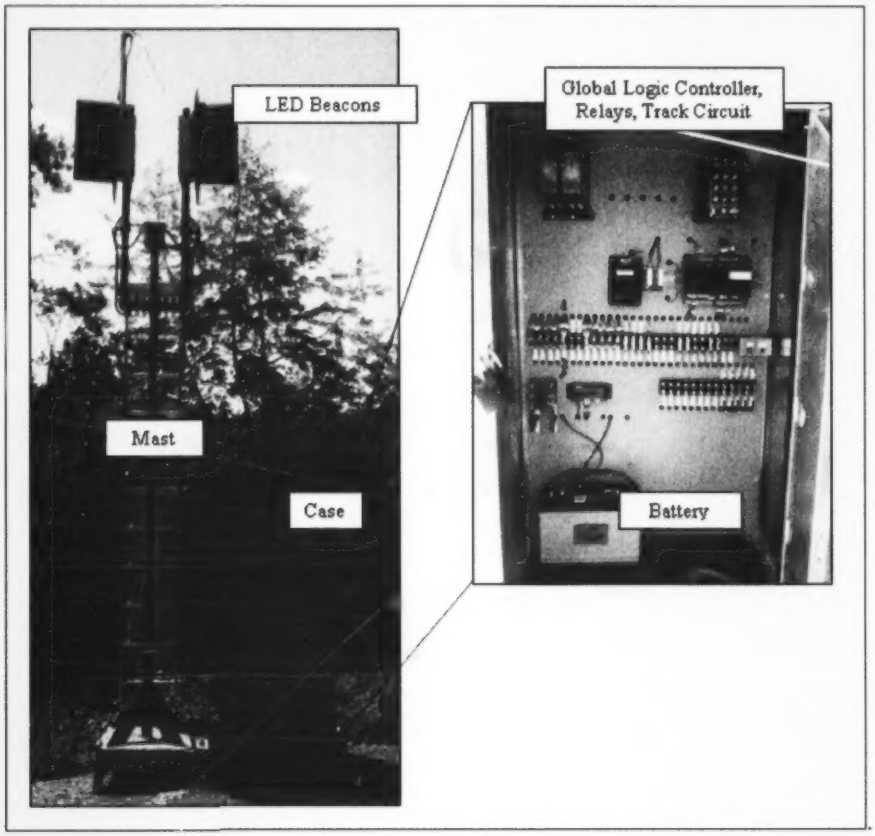

Figure 6.2 - FAS-PAS System and Major Components

6.3 Testing Methodology

Global Rail's FAS-PAS system was tested for its ability to consistently and accurately identify switch position and convey this information to the train engineer. The testing methodology was as follows:

1. A test site was selected in consultation with NB Southern Railway to provide easy accessibility and frequent switching activity. The unit was installed under the supervision of the supplier at the selected location.

2. The warning device was tested from April 2005 to March 2007, ensuring the system was exposed to a variety of weather conditions.

3. The visual aspect of the system was tested as follows:
    a. Visibility of LED signal from a set distance (i.e., ¼, ½, 1 mile from switch) was logged by the locomotive engineer.
    b. Weather conditions were noted to determine impact on LED visibility:
        i. Impact of ice buildup on LED lens
        ii. Diminished visibility in rain, snow, etc.
        iii. Impact of natural light conditions
        iv. Functionality in extreme temperatures
    c. The LED indication was compared against actual switch position and mechanical target.

4. The radio aspect of the system was tested by
    a. Comparing radio query responses with actual switch position, LED indication, and mechanical target. Results were logged by the train engineer. To provide further testing, the Hi-Rail was also used to test the radio system at regular intervals.
    b. Monitoring the reliability of the radio system at specified distances and under varying weather conditions.
    c. Using a Hi-Rail vehicle to test the response of the system when the switch is changed following a query.
    d. Recording any occurrences of radio interference (hot box detectors, other trains, etc.).

5. The power supply was monitored to determine susceptibility to environmental conditions. The train engineers also logged any malfunctions.

6. Overall system performance was monitored, including:
    a. signal changes when switch position is altered,

b. amount of gap present between switch points and rails before signal aspect will change,
c. correct colour aspect provided for switch position,
d. success of fail-safe features.

Operation in non-signalled territory is governed by CROR OCS Rules 301–313. The handling of switches in non-signalled territory is found in CROR Rule 104. Consequently, Rule 104 was followed during testing and any conflicting information provided to the train engineer during the testing period was ignored in favour of railway operating rules.

7.0 DATA ANALYSIS AND SYSTEM PERFORMANCE

The FAS-PAS system was evaluated for its ability to accurately and consistently relay switch position both visually and verbally to the locomotive engineer. Data, such as weather conditions, train speeds, LED visibility, whether correct audio signal was displayed and others were collected to quantify the effectiveness of the system. This information is presented in sections 7.1 through 7.6. Completed switch logs completed by locomotive engineers can be found in Appendix C.

7.1 LED Signals

The LED display unit used in this system, as seen in Figure 7.1, is a critical component used to give the locomotive engineer a visual indication of the switch position. A two-colou single aspect LED, displaying either a red or green signal, informed engineers as to whether the switch was lined for the main-line or not lined properly. The signals were mounted on a mast at a height of approximately 4.6 m.

The LED display was monitored to determine how visible it was and how accurately it detected switch position. The display was visible a minimum of 1.6 km from the switch (along a tangent section of track).

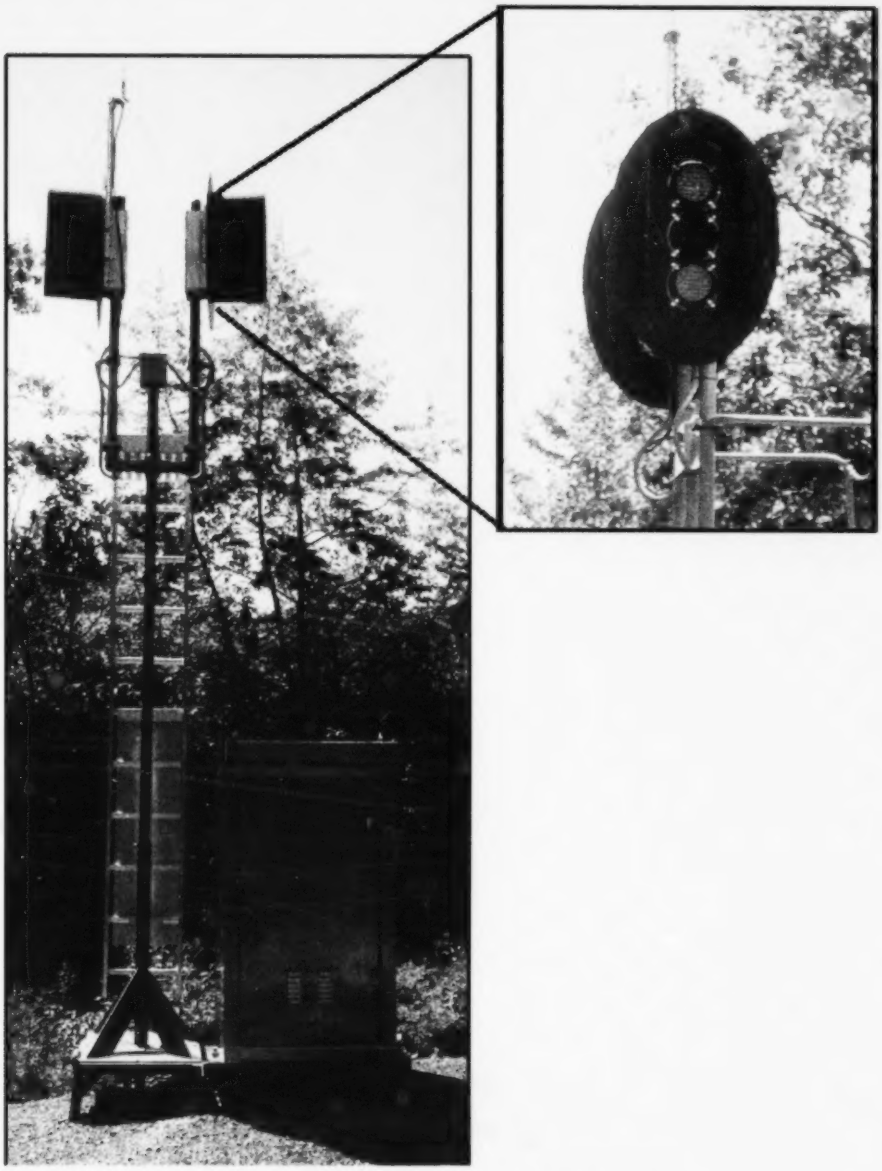

Figure 7.1 - View of Mast and LED Signals

The first element examined was the visibility of the display. Locomotive engineers were asked to comment on LED visibility and classify as either *good*, *fair*, or *poor*. Weather was noted to determine the impact of different conditions such as fog, snow, or rain on the visibility of the signals. There were 341 observations (trains and Hi-Rails) made by

engineers between May 2005 and March 2007. Table 7.1 gives a breakdown of the percentage of observations for each visibility classification.

Table 7.1- Percentage of Observations for Each Visibility Classification

Classification	Number of Observations	Percentage
Good	336	99%
Fair	5	1%
Poor	0	0

In instances where a *fair* or *poor* classification was made, the weather conditions at the time were viewed to determine whether inclement weather influenced visibility. There were only five observations where visibility was classified as *fair* and no instances where *poor* visibility was cited. These cases are listed in Table 7.2.

Table 7.2 - Instances of Fair Visibility and Associated Weather Conditions

Date	Weather	LED Visibility
August 13, 2005	Rain	Fair
August 15, 2005	Clear	Fair
September 26, 2005	Rain	Fair
January 23, 2006	Snow	Fair
January 31, 2006	Clear	Fair

On two of the days that visibility was classified as fair, the weather was sunny and clear; however, visibility would be expected to be at its best during such conditions. Glare from the sun most likely made it difficult to see the LED.

There are most certainly instances where visibility would be reduced; however, it appears that under most conditions, the LED signal is very discernible. It should be noted that visibility is a subjective attribute and what one locomotive engineer thinks is *good* may be *fair* to another and vice versa.

The second condition monitored with respect to the LED signals was whether they were displaying the same information shown by the mechanical target. A contradiction between the colour being displayed by the LED and the colour of the facing target is not

a desirable situation and undermines the validity of the system. There were no instances recorded where the LED signal did not match the colour of the mechanical target.

7.2 Impact of Weather

Weather is another factor affecting operation of the system. The ability to withstand extreme weather conditions is a good indication of system robustness. This is particularly true during winter months where cold temperatures, snow, and freezing rain can create a number of particularly challenging environments.

In comparison to past winters, the first winter of testing (2005-06) was relatively mild. The average temperature for December 2005 to March 2006 was -3.9°C while the average for the same period in the previous year was -6.5°C. Snowfall amounts were lower as well, with a monthly average of 25.1 cm and 43.6 cm for the same periods, respectively.

The second winter of testing (2006-07) was more representative of a typical New Brunswick winter. The average temperature was -6.1°C from December 2006 to March 2007. The average monthly snowfall was 36.8 cm over the same period. The month of February 2007 provided a series of particularly cold nights with lows reaching into the -20s for 12 different days throughout the month. The coldest temperatures were recorded in early March 2007: -26°C for two consecutive nights. Despite these cold temperatures, the system performed without incident.

The visibility of the LED signals does have the potential to be reduced, as mentioned in section 7.1; however, even under less than ideal conditions, the signals appeared to be very noticeable from a long distance away. Snow and ice buildup around the signal heads was not noted as a problem during testing.

The components of the system were not affected in any way by the extreme heat or cold that was experienced during summer and winter months. No issues or failures of any of the components were reported throughout testing.

7.3 Radio Signal

In addition to the visual signal, the locomotive engineer has the option to query the system via radio and receive in response an audible indication of switch position. When the code corresponding to the particular switch location is punched into the keypad of the VHF/UHF radio on the locomotive, a digital audio message is relayed back to the engineer. There are two possible messages; one message indicates the switch is lined in the normal position and the other that it is not lined. The audible message should be able to be heard a minimum of 6.4 km from the switch. A passive sign (see Figure 7.2) is placed in advance of the switch in each direction to serve as a reminder to train crew to query the system. The sign states the milepost location of the switch and corresponding code required for the query.

There are two main attributes of the radio transmission that indicate whether it is functioning properly. The first is simply whether the system responds to the query. It is possible that, due to interference, poor weather or some other factor, no response is received by the locomotive engineer. In such a situation the engineer can either continue to query the system or rely entirely on the visual signals and mechanical targets instead.

Figure 7.2: Passive Sign

The second attribute that must be considered is the accuracy of the radio response. Accuracy is defined by the ability of the system to return a message that correctly identifies the switch position and matches the information being presented by the LED signal and mechanical targets.

During the testing of the FAS-PAS system, locomotive engineers were asked to comment on the quality of the radio transmission, noting any occasions where it failed to respond or where the response returned did not match that of the LED signal. There were 341 observations made by engineers between May 2005 and March 2007. Problems regarding the radio signal that were encountered during the testing phase of this project are outlined in Table 7.3.

Table 7.3 - Problems/Issues with Radio Signal Encountered During Testing

Date	Time	Weather	Speed (mph)	Travel Direction eastbound or westbound	Correct Audio Signal Returned?	Problems / Comments
May 26 2005	14:25	Rain	30	W	Yes	Audio signal not returned until 2.2 km from the switch. Data do not indicate anything out of the ordinary.
June 28 2005	23:40	Clear	N/A	W	No response	Problem with tower, RTC advised. No record shown on switch log.
Aug 15 2005	23:30	Clear	30	E	No response	No response following query. No record shown on switch log.
Aug 17 2005	14:25	Clear	28	W	No response	No response following query. No indication of switch query. Short duration sequence (18 sec).
Aug 17 2005	19:35	Clear	30	E	No response	No radio signal. No indication of Switch query. Short duration sequence (51 sec).
Aug 18 2005	3:10	Clear	30	W	Yes	Queried 5 times before audio response was returned. Normal sequence in switch log.
Sept 6 2005	19:00	Clear	30	W	No response	No response was returned after keying #. No indication of switch query. Short duration sequence (30 sec).
Feb 22 2006	23:20	Clear	38	E	No response	Queried 4 times with no response.
Sept 14 2006	16:50	Clear	37	E	Yes	Audio signal not returned until third try.
Sept 14 2006	20:50	Clear	31	W	Yes	Audio signal not returned until second try.

There were 10 cases in which the system either required multiple queries to obtain a response or did not respond at all. On May 26, 2005, an audio signal was returned but was delayed until 2.2 km from the switch. Poor weather conditions (rain) may have had an influence in this occurrence but there is no way to confirm. The remaining problems occurred on days where weather conditions were classified as clear. On August 18, 2005, and September 14, 2006, the system was queried multiple times before receiving a response. The system's internal switch logs confirm the activation of the system but do not show the initial attempts.

On June 28 and August 15, 2005, no response was received following the switch query and no record was found in the switch logs. However, the system did activate a visual indication of switch position that was noted by the locomotive engineer. This indicates that the failure was most likely a transmission issue and not a problem with the systems ability to detect switch position.

Typical switch log sequences, including the query of the system, verification of switch position, activation of the LED display, and deactivation of the system, are approximately 5 minutes in duration. On August 17 and September 6, 2005, the sequence shown in the switch log was much shorter, as noted in Table 7.3; durations were in the range of 18 to 51 seconds. No audio response was received for either of the days; a visual indication was presented however.

7.4 Change in Switch Position

Due to the fact the switch in this location is rarely operated, the position of the switch was changed periodically to ensure the system was responding properly and able to recognize changes in switch position. Hi-Rail operators performing regular maintenance checks would query the system, confirm that it responded, and then adjust the position of the switch to ensure it reacted accordingly. This typically occurred on a weekly basis. In all instances except one, the system performed as intended. Under one specific scenario the system did not respond as expected. As described below, the movement of a switch immediately following a query would return an unexpected result.

The FAS-PAS system was set up in such a manner that the audio message was recorded on a 20-second block; approximately 6 seconds were occupied by the recorded message. After the switch had been queried, the appropriate message was returned, leaving approximately 14 seconds of space on the original 20-second audio block. If the switch position was changed following a query, a new message would be returned to notify of

the change. If the switch was moved before the original audio message had timed out (i.e., there was still time remaining in the original 20-second recording), the new message used the remaining time. However, this caused a problem if the 20 seconds ran out before the message was finished; the message was cut off and not replayed. In this situation, the locomotive engineer may not be provided sufficient warning of the change that has occurred.

7.5 Power Source

The FAS-PAS system is powered by a 12 V marine-grade deep cycle battery continually charged by two 80 W solar panels. Due to the low train volumes passing through the test site, there was never a significant draw on the battery. In the winter months when days are shortest and solar energy is at its lowest, no issues with respect to power were noted.

Throughout the test period, the battery voltage levels under load were periodically measured. A summary of these measurements is found in Table 7.4.

Table 7.4 - Summary of Battery Measurements

Date	Battery Level (Volts)
November 21, 2005	14.30
December 21, 2005	14.72
January 9, 2006	12.85
February 6, 2006	14.55
March 6, 2006	14.30
April 10, 2006	14.15
May 8, 2006	14.04
June 14, 2006	14.04
July 18, 2006	14.15
August 9, 2006	14.10
September 12, 2006	14.15
October 16, 2006	14.15
November 11, 2006	12.90
December 14, 2006	12.85
January 8, 2007	12.85
February 7, 2007	15.12
March 13, 2007	14.24
March 25, 2007	14.38

7.6 Equipment Installation

The installation of the FAS-PAS system was a relatively straightforward and fast process. The physical installation took place on May 19, 2005. A backhoe was used to dig a hole in which to place the base of the unit (Figure 7.2) as well as a trench to run cable from the cabinet to the solar panel. The solar panel, typically attached directly to the unit, was mounted independently due to the presence of trees in the area. Once the base was backfilled, the cabinet and mast were mounted. A small trench was dug under the tracks (Figure 7.3) to pass a section of conduit carry wires from the cabinet to the switch circuit controller seen in Figure 7.4.

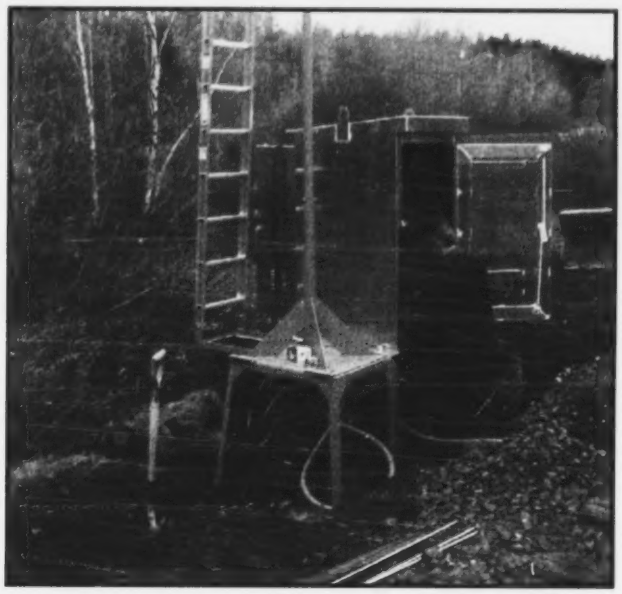

Figure 7.2 - Base of Unit Prior to Backfilling

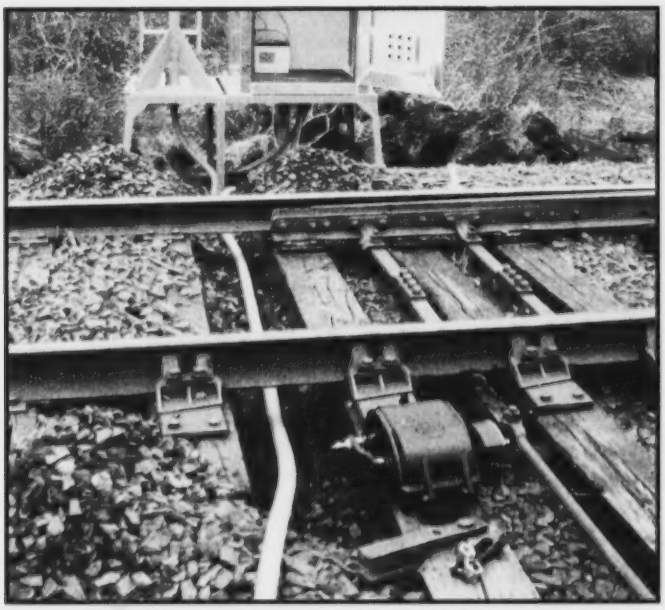

Figure 7.3 - View of Trench and Conduit Running Under Tracks

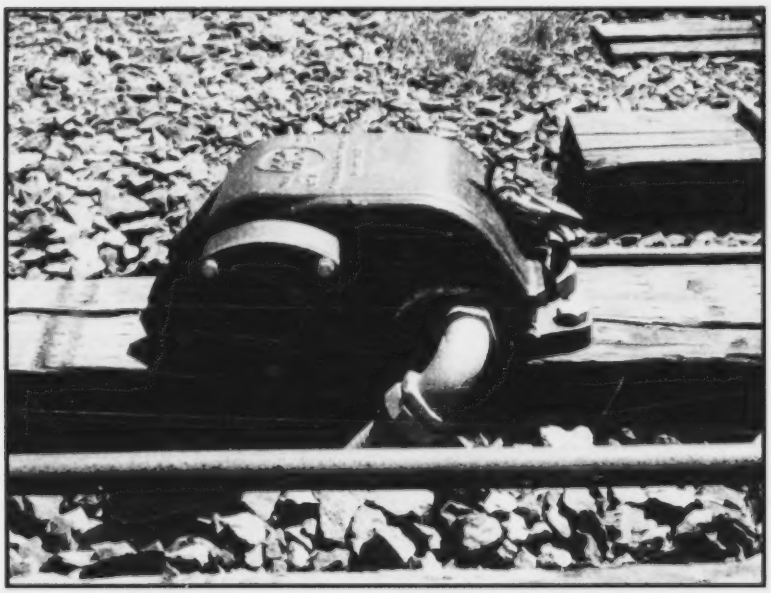

Figure 7.4 - Switch Circuit Controller

On May 20, the contacts of the switch circuit controller were adjusted to ensure proper identification of switch position. Minor adjustments were made to the electronic hardware contained in the cabinet (Figure 7.5). The calibration process required less than a half a day to complete, at which time the unit was fully operational.

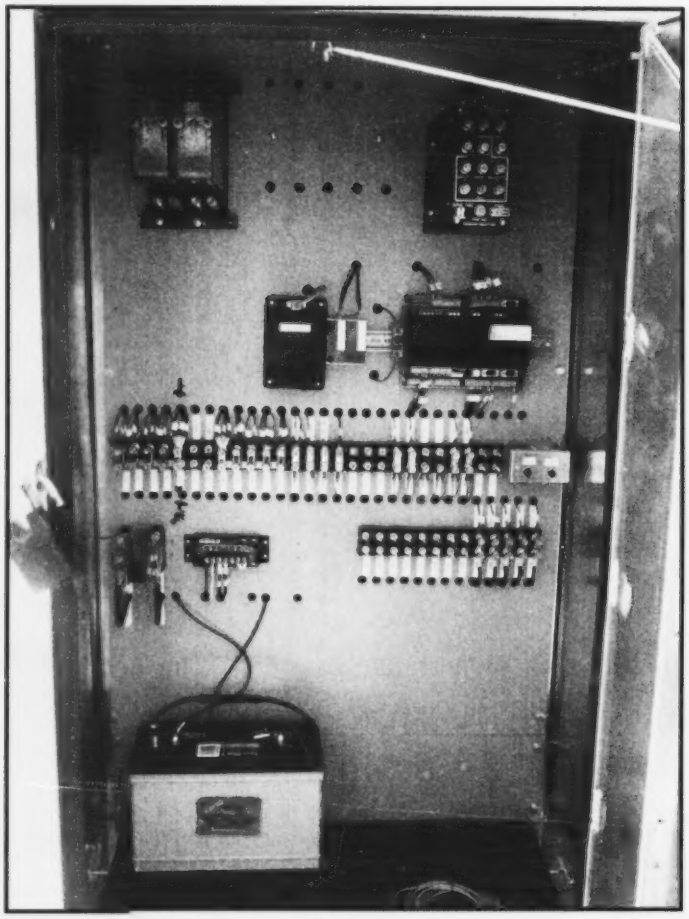

Figure 7.5 - View Inside of Cabinet

8.0 CONCLUSIONS

The switch position indication system being tested is essentially a subsystem of the FAS-PAS remote switch point operation system developed by Global Rail Systems. The system, as delivered, was relatively easy to install, requiring minimal equipment and approximately 10 to 12 person-hours of labour. To date, the system has proven to be dependable, accurate, and relatively maintenance-free.

There were 341 observations made by engineers (of both trains and Hi-Rails) during the study period of May 2005 to March 2007. Nearly all (98%) of the audio queries had a system response (all of which gave the correct switch position). The remaining two percent (6 queries) did not return an audio response to the operators. It is unknown whether the underlying problem for these six queries lies with operator error (keying in the access code) or with inadequate radio signal. There were an additional four cases (1%) in which the system required a second or third query to obtain a system response. In all instances where the switch position was successfully communicated by digital audio message, the corresponding correct LED visual indication was displayed on site. An incorrect switch position was never communicated (either visually or audibly).

Observation logs indicated that LED lights were visible under a variety of weather conditions. Among the 341 observations, 264 (99%) were classified as *good* visibility and 5 (1%) were classified as *fair* visibility. There were no observations classified as *poor* visibility.

Throughout the study period, the power requirements were fully met by the solar system.

9.0 RECOMMENDATIONS

The following recommendations have been formulated as a result of the study findings:

- Given the positive study results, an expanded testing programme is warranted. The testing regime should include multiple sites that involve increased train speeds, volumes and switch activity. An expanded series of testing would ensure system robustness.

- A small glitch regarding the logic for the broadcasting of the digital audio message was uncovered during testing (see section 7.4). If the switch position is changed at the same time that the switch position is being broadcast, it is possible that the new position may not be re-broadcast. A minor change to the system software should overcome this problem.

- Future versions of this system should draw upon solar experience of the rail industry from western Canada:
    - to size solar capacity
    - cover solar panels with lexan to mitigate vandalism concerns
    - use black coloured frame to enhance melting of snow/ice

- Should this product eventually prove worthy for field implementation, the manufacturer should repackage the system in a smaller (more cost-effective) housing. The current structure is designed to house the full FAS-PAS system.

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APPENDIX A – *DESCRIPTION OF REQUIREMENTS SENT TO SUPPLIERS*

The University of New Brunswick has partnered with Transport Canada and the New Brunswick Department of Transportation to establish a research program for testing intelligent transportation system (ITS) products in rural environments. Researchers in the University's Transportation Group are currently seeking ITS technology that could be used to improve rail safety in two areas: 1) highway-rail intersections and 2) switch positions. At least one ITS product will be selected for each problem area by January 31, 2005 and then tested over the following 12-month period. Successful suppliers are expected to provide input to the research effort.

Potential products must be suitable for the Canadian environment and cost less than traditional systems in use today while providing equal or greater safety benefits. Further details on the product requirements are provided below for each problem area. For more information, please contact Dr. Eric Hildebrand, Transportation Group Coordinator at the UNB Department of Civil Engineering.

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Highway Rail Intersections

A low-cost ITS-based warning system is being sought for intersections between railways and private roads and farm crossings. Typically, these crossings are equipped only with warning signs. Potential warning systems should cost much less than the $100,000 required for existing warning systems, operate independently of train and rail company equipment, have a stand-alone power supply, and have a failure reporting feature.

Switch Position Indicator

Researchers also want to test an ITS-based product that would give train crews advance warning of the position of hand-operated switches along non-signalled sections of track. Potential systems should be relatively low-cost, have a stand-alone power supply, and have a failure-reporting feature.

APPENDIX B – *FAS-PAS SYSTEM SUPPLEMENTARY INFORMATION*

ADVANCE SWITCH POINT POSITION INDICATION IN DARK TERRITORY

A Global Rail Systems Solution

Dark Territory

Defined as a section of railroad where the trains are allowed to proceed by any means of train control other than a signal system.

There are many different methods of train control for dark territory, but all of the methods for train control in dark territory are rule-based. There is generally no automation or signaling equipment for advance warning of occupancy, broken rail, switch point position, or fouling of tracks at switch points. When a mechanical spring switch is utilized in dark territory, a switch point indicator with an advance signal on the facing point side of the switch is provided if the train speed is greater than 20 mph. Other than the spring switch scenario, no indicators for switch point position are provided except for the mechanical target mounted on the switch stand.

Most traffic in dark territory is limited to 49 mph or less depending on the rating of the rail and surface. The traffic is generally lighter in density and the Return On Investment (ROI) for a signal system is very difficult to justify. Global Rail Systems Inc has developed an automation system for dark territory switch control and switch point position indication. This system is called FAS-PAS™ and has successfully been deployed in the USA at 28 different locations.

FAS-PAS

The FAS-PAS™ system provides switch point position indication for normal, reverse, and not lined positions, via a three color single aspect switch point position indicator, in addition to an audio announcement over the railroad's VHF – UHF radio frequencies. The FAS-PAS system also incorporates a power operated spring switch that provides the railroad the ability to remotely control the switch from the locomotive or from the dispatcher's console. Additionally, the FAS-PAS system utilizes two vital track circuits for both the main and turnout sides of the switch layout. These track circuits are used to lock the switch.

For typical dark-territory applications the FAS-PAS system has an ROI of less than one year. This ROI is realized based on increased asset utilization (time and equipment), risk reduction and fuel savings.

Transport Canada

Global Rail Systems has been asked to provide a solution to Transport Canada for an advance switch position information system without the ability to remotely control the switch.

Utilizing the designs already incorporated in the FAS-PAS system, Global Rail has developed three separate solutions that provide increasing levels of functionality. In this manner the end user can choose the application that best fits their operating requirements.

1. A tandem two color single aspect switch position indicator at the switch point along with a mechanical target.

2. Mechanical target on switch stand with VHF – UHF radio voice announcement for advance switch point position indication.

3. A mechanical target on the switch stand with a tandem two color single aspect switch position indicator at the switch point in conjunction with the VHF – UHF radio voice announcement for advance switch point position indication.

Each method will provide advance switch point position indication information to an approaching train. Acquisition costs differ with each solution and the operating rules associated with each solution will also differ.

Method 1

This method utilizes tandem (back to back) two color single aspect switch position indicators. The colors utilized will be green for the Normal position and red for not Normal.
The equipment and logic at the switch will determine switch point position. The switch point position indicator will be constantly illuminated and is mounted on the mast at a height of 15 feet. The switch point position indicator can be seen a minimum of 1 mile (with tangent track) from the switch.

As long as the switch points remain properly lined in the normal position then the green aspect will be displayed. If the switch points are gapped open greater than ¼ of an inch from the normal position, the indicator will display a red indication until the switch points are determined to be properly closed to the normal switch point.

The benefits of implementing method 1 are as follows:

1. The switch point position indicator provides a confirming point position indication that can be seen a minimum of 1 mile in advance of the switch providing that the track is tangent.

Method 2

This method utilizes a VHF/UHF radio to provide an audible indication of the switch point position. There are no tandem switch point indicators at the switch. This method will provide an audible message indicating if the switch points are properly lined normal. When a train or equipment radios a request for verification of the normal position of the switch, the equipment and logic at the switch will respond to the request for switch point position verification. Once the equipment and logic has verified the switch points are lined normal, an audible message stating "switch normal" will be broadcast over the voice radio informing the train crew that the switch is properly lined normal. The audible message can be heard a minimum of 4 miles from the switch. A passive sign is placed in advance of the switch point in each direction, which states the milepost of the location and informs the train crew that they need to request switch position verification.

If the switch points are gapped open greater than ¼ of an inch from the normal position, an audible message of "switch not lined" will be broadcast over the radio. This audible message can be repeated periodically on a timed cycle if required or it will broadcast the switch not lined message only when a switch point position verification request is received.

The benefits of implementing method 2 are as follows:

1. The rules require the trainmen to request the switch point position sufficiently in advance of the switch to allow the train to safely stop before getting to the switch.

2. The audible message will inform the trainmen of the position of the switch well in advance of the switch (4 miles).

Method 3

This method combines method 1 and 2 to provide both the audio indication and visual indicators. The equipment and logic at the switch will respond to the request for switch point position verification by determining that the switch is properly lined normal. Once the equipment and logic has verified this, then an audible message stating "switch normal" will be broadcast over the voice radio informing the train crew that the switch is properly lined normal. The switch point position indicator can be seen a minimum of 1 mile (with tangent track) from the switch. The audible message can be heard a minimum of 4 miles from the switch. A passive sign is placed in advance of the switch point in each direction, which states the milepost of the location and informs the train crew that they need to request switch position verification.

If the switch points are gapped open greater than ¼ of an inch from the normal position, the indicator will display a red indication and an audible message of "switch not lined" will be broadcast over the radio. The audible message can be repeated periodically on a timed cycle if required or it will broadcast the switch not lined message only when a switch point position verification request is received. The benefits of implementing method 3 are as follows:

1. The rules require the trainmen to request the switch point position verification and receive the proper response sufficiently in advance of the switch to allow the train to safely stop before getting to the switch in the event the switch is not properly lined.

2. The audible message will inform the trainmen of the position of the switch well in advance of the switch (4 miles).

3. The switch point position indicator provides a confirming point position indication that can be seen a minimum of 1 mile in advance of the switch providing that the track is tangent.

Recommended Solution

Of the three methods proposed, Global Rail Systems prefers and recommends the third method. This method, while having slightly higher acquisition costs, will provide the earliest possible indication of switch point position along with a highly visible indication that can be seen in most circumstances well in advance of the switch points. This solution provides redundant methods of indicating the position of the switch in advance of the switch points and provides the greatest opportunity for a train to take corrective action in the event the switch points are not properly lined. Additionally, the equipment utilized in this method is a subset of the equipment utilized in the FAS-PAS system and provides a migration path to a fully automated switch solution.

APPENDIX C – *SWITCH OBSERVATION LOGS*

Observation Log Westfield Beach Switch Position Indicator #014 6101

Date 2005	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
May 26	14:25	Rain	30	W	Y	G	Y	Audio signal not returned until 12.6 Mile.
May 27	2:50	Rain	30	E	Y	G	Y	
May 27	14:45	Rain	30	W	Y	G	Y	
May 27	22:15	Rain	30	E	Y	G	Y	
May 27	7:28	Cloudy	20	E	Y	G	Y	Threw the switch lights came on red. Lined switch to normal; everything worked properly.
June 3	9:05	Sunny	20	W	Y	G	Y	Everything works properly.
June 6	0:15	Rain	30	W	Y	G	Y	
June 7	17:35	Rain	30	E	Y	G	Y	
June 9	2:50	Clear	30	W	Y	G	Y	
June 9	17:00	Dark	30	E	Y	G	Y	
June 10	8:35	Fog	20	W	Y	G	Y	
June 10	12:35	Clear	30	W	Y	G	Y	
June 11	6:25	Fog	30	E	Y	G	Y	
June 17	9:17	Rain	20	W	Y	G	Y	
June 24	5:22	Clear	N/A	W	Y	G	Y	
June 24	10:06	Clear	20	W	Y	G	Y	
June 25	22:45	Clear	N/A	E	Y	G	Y	
June 27	7:12	Clear	N/A	W	Y	G	Y	
June 27	20:00	Clear	N/A	W	Y	G	Y	

Date 2005	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
June 28	23:40	Clear	N/A	W	Y	G	Nil	Problem with tower, RTC advised.
June 28	0:01	Clear	30	W	Y	G	Y	
June 28	18:30	Clear	30	E	Y	G	Y	
June 29	20:35	Clear	N/A	E	Y	G	Y	
June 30	4:00	Rain	30	E	Y	G	Y	
July 1	0:18	Clear	30	E	Y	G	Y	
July 1	7:40	Rain	N/A	W	Y	G	Y	
July 1	15:35	Rain	N/A	E	Y	G	Y	
July 3	22:55	Clear	N/A	W	Y	G	Y	
July 15	9:41	Clear	20	W	Y	G	Y	
July 22	12:13	Clear	10	E	Y	G	Y	
Aug 5	8:46	Cloudy	10	W	Y	G	Y	
Aug 12	14:29	Clear	10	E	Y	G	Y	
Aug 13	21:30	Rain	30	W	Y	F	Y	
Aug 15	23:30	Clear	30	E	Y	F	N	Punched in the code and received no response.
Aug 16	21:35	Clear	30	W	Y	G	Y	
Aug 17	2:45	Clear	30	E	Y	G	Y	
Aug 17	14:25	Clear	28	W	Y	G	N	No radio signal.
Aug 17	19:35	Clear	30	E	Y	G	N	No radio signal.
Aug 18	3:10	Clear	30	W	Y	G	Y	Punched the code in 5 times before audio response was returned.
Aug 19	0:25	Clear	28	W	Y	G	Y	

Date 2005	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Aug 19	9:05	Clear	10	W	Y	G	Y	
Aug 20	8:15	Clear	28	E	Y	G	Y	
Aug 20	14:12	Cloudy	30	W	Y	G	Y	
Aug 21	4:05	Cloudy	30	W	Y	G	Y	
Aug 21	9:27	Clear	20	W	Y	G	Y	
Aug 21	22:30	Fog	30	W	Y	G	Y	
Aug 22	19:20	Clear	30	E	Y	G	Y	
Aug 26	13:40	Clear &	30	W	Y	G	Y	
Aug 27	3:55	Clear	30	E	Y	G	Y	
Aug 30	2:45	Clear	30	W	Y	G	Y	
Aug 30	17:25	Rain	30	E	Y	G	Y	
Sept 1	1:30	Rain	30	E	Y	G	Y	
Sept 1	18:00	Clear	30	E	Y	G	Y	
Sept 2	23:00	Clear	30	W	Y	G	Y	
Sept 3	19:30	Clear	30	E	Y	G	Y	
Sept 6	19:00	Clear	30	W	Y	G	No response	No response was returned after dialing #.
Sept 7	16:30	Clear	27	E	Y	G	Y	
Sept 8	21:30	Clear	27	W	Y	G	Y	
Sept 9	18:15	Clear	28	E	Y	G	Y	
Sept 16	9:13	Clear	15	W	Y	G	Y	
Sept 16	10:28	Clear	30	W	Y	G	Y	
Sept 17	2:55	Clear	30	E	Y	G	Y	

Date 2005	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Sept 18		Clear	30	W	Y	G	Y	
Sept 19		Rain	30	E	Y	G	Y	
Sept 20		Clear	30	W	Y	G	Y	
Sept 21		Clear	30	E	Y	G	Y	
Sept 23	10:01	Rain	12	W	Y	G	Y	
Sept 25		Clear	30	W	Y	G	Y	
Sept 26		Rain	30	E	Y	F	Y	
Sept 28		Clear	30	W	Y	G	Y	
Sept 30	13:47	Clear	20	W	Y	G	Y	
Oct 7	9:14	Fog	10	W	Y	G	Y	
Oct 16	19:15	Rain	30	W	Y	G	Y	
Oct 17	22:52	Clear	30	E	Y	G	Y	
Oct 21	8:53	Clear	10	W	Y	G	Y	
Sept 28		Clear	30	W	Y	G	Y	
Oct 16	19:15	Rain	30	W	Y	G	Y	
Oct 17	22:52	Clear	30	E	Y	G	Y	
Oct 28	2:22	Clear	40	E	Y	G	Y	
Oct 29	11:00	Clear	40	W	Y	G	Y	
Oct 30	10:50	Clear	28	E	y	G	Y	
Oct 30	23:10	Clear	29	W	Y	G	Y	
Oct 31	22:41	Clear	25	E	Y	G	Y	
Nov 4	9:03	Clear	10	W	Y	G	Y	

Date 2005	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Nov 11	8:10	Clear	10	W	Y	G	Y	
Nov 29	18:55	Clear	21	W	Y	G	Y	
Nov 30	17:00	Rain	35	E	Y	G	Y	
Dec 2	3:30	Clear	32	W	Y	G	Y	
Dec 5	18:10	Clear	30	E	Y	G	Y	
Dec 5	22:55	Clear	31	W	Y	G	Y	
Dec 6	14:45	Clear	36	E	Y	G	Y	
Dec 6	19:45	Clear	27	W	Y	G	Y	
Dec 7	21:45	Clear	27	E	Y	G	Y	
Dec 8	11:15	Clear	29	W	Y	G	Y	
Dec 9	2:30	Clear	27	E	Y	G	Y	
Dec 9	10:45	Clear	30	W	Y	G	Y	
Dec 9	17:20	Snow	39	E	Y	G	Y	
Dec 10	15:35	Clear	40	W	Y	G	Y	
Dec 10	21:55	Flurries	40	E	Y	G	Y	
Dec 11	1:00	Clear	40	W	Y	G	Y	
Dec 11	4:30	Clear	31	W	Y	G	Y	
Dec 12	8:35	Overcast	15	E	Y	G	Y	
Dec 12	19:25	Clear	40	E	Y	G	Y	
Dec 13	4:30	Clear	40	E	Y	G	Y	
Dec 13	18:54	Snow	30	W	Y	G	Y	
Dec 14	16:45	Clear	25	E	Y	G	Y	

Date 2005	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Dec 14	22:30	Clear	28	W	Y	G	Y	
Dec 15	2:05	Clear	30	W	Y	G	Y	
Dec 15	19:30	Clear	26	E	Y	G	Y	
Dec 16	0:35	Rain	30	E	Y	G	Y	
Dec 17	9:05	Snow/Fog	25	W	Y	G	Y	
Dec 18	0:40	Clear	29	W	Y	G	Y	
Dec 18	2:40	Clear	27	E	Y	G	Y	
Dec 19	8:33	Clear	10	W	Y	G	Y	
Dec 19	19:45	Clear	31	W	Y	G	Y	
Dec 20	6:30	Clear	28	E	Y	G	Y	
Dec 20	17:10	Clear	38	E	Y	G	Y	
Dec 21	23:50	Clear	27	W	Y	G	Y	
Dec 23	2:45	Clear	27	E	Y	G	Y	
Dec 23	10:40	Light Snow	27	W	Y	G	Y	
Dec 24	9:15	Clear	27	E	Y	G	Y	
Dec 28	21:25	Clear	27	W	Y	G	Y	
Dec 30	8:10	Fog Rain	10	E	Y	G	Y	

Date 2006	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Jan 3	20:55	Rain	32	E	Y	G	Y	
Jan 6	6:30	Clear	34	E	Y	G	Y	
Jan 6	18:20	Fog	30	W	Y	G	Y	
Jan 8	11:15	Clear	31	E	Y	G	Y	
Jan 8	20:27	Clear	27	W	Y	G	Y	
Jan 9	12:55	Snow	30	E	Y	G	Y	
Jan 9	18:40	Rain	32	W	Y	G	Y	
Jan 10	13:10	Clear	30	E	Y	G	Y	
Jan 10	19:50	Clear	30	W	Y	G	Y	
Jan 11	14:15	Rain	30	E	Y	G	Y	
Jan 11	19:00	Clear	34	W	Y	G	Y	
Jan 12	12:03	Clear	33	E	Y	G	Y	
Jan 12	19:27	Clear	30	E	Y	G	Y	
Jan 13	17:20	Clear	30	E	Y	G	Y	
Jan 13	23:30	Clear	26	W	Y	G	Y	
Jan 14	13:45	Rain	30	E	Y	G	Y	
Jan 14	20:50	Clear	30	W	Y	G	Y	
Jan 15	17:35	Rain	30	E	Y	G	Y	
Jan 17	19:45	Clear	30	W	Y	G	Y	
Jan 18	13:45	Rain	30	E	Y	G	Y	
Jan 19	20:35	Clear	30	W	Y	G	Y	

Date 2006	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Jan 20	12:35	Clear	30	E	Y	G	Y	
Jan 21	21:20	Clear	30	W	Y	G	Y	
Jan 22	13:10	Clear	30	E	Y	G	Y	
Jan 23	19:40	Snow	25	W	Y	F	Y	
Jan 24	14:35	Clear	30	E	Y	G	Y	
Jan 25	20:10	Snow	18	W	Y	G	Y	
Jan 26	13:30	Clear	30	E	Y	G	Y	
Jan 27	19:40	Clear	30	W	Y	G	Y	
Jan 28	14:22	Clear	27	E	Y	G	Y	
Jan 30	19:20	Clear	39	W	Y	G	Y	
Jan 31	15:33	Clear	33	E	Y	F	Y	
Jan 31	19:25	Clear	34	W	Y	G	Y	
Feb 1	15:00	Snow	30	E	Y	G	Y	
Feb 1	19:40	Clear	20	W	Y	G	Y	
Feb 2	14:15	Clear	35	W	Y	G	Y	
Feb 2	19:50	Clear	30	E	Y	G	Y	
Feb 3	15:55	Clear	32	E	Y	G	Y	
Feb 3	21:20	Clear	20	W	Y	G	Y	
Feb 4		Rain	30	W	Y	G	Y	
Feb 4	14:25	Clear	34	E	Y	G	Y	
Feb 5		Clear	30	E	Y	G	Y	

Date 2006	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Feb 6	19:20	Clear	20	W	Y	G	Y	
Feb 7	14:00	Clear	36	E	Y	G	Y	
Feb 7	20:20	Clear	30	W	Y	G	Y	
Feb 8	15:00	Clear	30	E	Y	G	Y	
Feb 8	21:20	Clear	20	W	Y	G	Y	
Feb 9	18:25	Clear	30	W	Y	G	Y	
Feb 10	15:45	Clear	30	E	Y	G	Y	
Feb 11	18:00	Clear	30	W	Y	G	Y	
Feb 12	17:45	Clear	30	E	Y	G	Y	
Feb 20	23:03	Clear	25	W	Y	G	Y	
Feb 21	14:23	Snow	35	E	Y	G	Y	
Feb 21	20:20	Snow	25	W	Y	G	Y	
Feb 22	23:20	Clear	38	E	Y	G	N	Tried 4 times, would not respond.
Feb 23	2:07	Fog	26	W	Y	G	Y	
Feb 23	17:30	Snow	30	E	Y	G	Y	
Feb 27	21:20	Snow	30	W	Y	G	Y	
Feb 28	16:40	Clear	34	E	Y	G	Y	
Mar 2	5:45	Clear	30	W	Y	G	Y	
Mar 2	0:30	Clear	30	E	Y	G	Y	
Mar 3	1:45	Snow	30	W	Y	G	Y	
Mar 4	4:01	Clear	18	W	Y	G	Y	

Date 2006	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Mar 4	17:58	Clear	34	W	Y	G	Y	
Mar 4	18:05	Clear	30	E	Y	G	Y	
Mar 14	19:40	Rain	25	W	Y	G	Y	
Mar 15	16:55	Clear	40	E	Y	G	Y	
Mar 16	3:35	Clear	30	W	Y	G	Y	
Mar 17		Clear	40	E	Y	G	Y	
Mar 18	21:10	Clear	30	W	Y	G	Y	
Mar 19	14:45	Clear	40	E	Y	G	Y	
Mar 22	19:00	Clear	27	W	Y	G	Y	
Mar 23	20:45	Clear	28	E	Y	G	Y	
Mar 24	21:00	Clear	27	W	Y	G	Y	
Mar 25	14:45	Clear	30	E	Y	G	Y	
Mar 27	20:40	Clear	40	W	Y	G	Y	
Mar 28	14:50	Clear	30	E	Y	G	Y	
Mar 30	1:20	Clear	40	W	Y	G	Y	
April 1	13:30	Clear	27	E	Y	G	Y	
April 3	23:20	Clear	27	W	Y	G	Y	
April 4	17:00	Clear	26	E	Y	G	Y	
April 5	20:15	Clear	27	W	Y	G	Y	
April 6	20:40	Clear	27	E	Y	G	Y	
April 7	23:00	Rain	25	W	Y	G	Y	

Date 2006	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
April 8	14:00	Clear	28	E	Y	G	Y	
Apr 17	19:25	Rain	30	W	Y	G	Y	
Apr 18	14:55	Clear	30	E	Y	G	Y	
June 13	19:40	Rain	30	W	Y	G	Y	
June 14	15:45	Clear	40	E	Y	G	Y	
June 15	18:00	Clear	30	W	Y	G	Y	
June 16	16:40	Clear	35	E	Y	G	Y	
June 17	21:30	Clear	40	W	Y	G	Y	
June 18	15:00	Clear	35	E	Y	G	Y	
Aug 3	22:10	Clear	34	W	Y	G	Y	
Aug 4	15:20	Clear	40	E	Y	G	Y	
Aug 4	20:45	Clear	25	W	Y	G	Y	
Aug 5	15:20	Clear	25	E	Y	G	Y	
Aug 6	22:15	Clear	30	W	Y	G	Y	
Aug 7	16:30	Rain	38	E	Y	G	Y	
Aug 8	19:45	Clear	39	W	Y	G	Y	
Aug 9	16:45	Clear	35	E	Y	G	Y	
Aug 3	06:50	Clear			Y	G	N	Turning switch too quick. It will say "switch is lined" and then throwing switch back it will say "switch is" and cut out.
Aug 9	11:15	Clear			Y	G	Y	
Aug 29	10:52	Rain			Y	G	Y	

Date 2006	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Aug 30	13:35	Clear		E	Y	G	Y	I throw switch before and after 2317 East. Query up switch and everything would be the way it should.
Aug 10	22:12	Rain	30	W	Y	G	Y	
Aug 11	15:40	Clear	30	E	Y	G	Y	
Aug 15	19:17	Clear	25	W	Y	G	Y	
Aug 16	17:07	Clear	40	E	Y	G	Y	
Aug 17	20:00	Clear	25	W	Y	G	Y	
Aug 18	15:25	Clear	40	E	Y	G	Y	
Aug 18	19:40	Clear	30	W	Y	G	Y	
Aug 19	14:20	Clear	30	E	T	G	Y	
Aug 20	20:15	Rain	25	W	Y	G	Y	
Aug 21	17:12	Clear	35	E	Y	G	Y	
Aug 22	20:53	Clear	23	W	Y	G	Y	
Aug 23	15:23	Clear	36	E	Y	G	Y	
Aug 24	13:09	Clear	31	W	Y	G	Y	
Aug 24	22:30	Clear	37	E	Y	G	Y	
Aug 25	21:40	Clear	30	W	Y	G	Y	
Aug 21	21:20	Clear	20	W	Y	G	Y	
Aug 22	16:10	Clear	25	E	Y	G	Y	
Aug 23	21:25	Clear	27	W	Y	G	Y	
Aug 24	16:35	Clear	30	E	Y	G	Y	

Date 2006	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Aug 24	19:57	Clear	28	W	Y	G	Y	
Aug 25	16:45	Clear	27	E	Y	G	Y	
Aug 26	16:20	Clear	38	E	Y	G	Y	
Aug 27	21:40	Clear	30	W	Y	G	Y	
Aug 28	19:20	Clear	30	E	Y	G	Y	
Aug 28	22:50	Clear	27	W	Y	G	Y	
Aug 29	16:06	Clear	36	E	Y	G	Y	
Aug 30	20:45	Clear	28	W	Y	G	Y	
Aug 31	15:20	Clear	37	E	Y	G	Y	
Sept 1	21:40	Clear	27	W	Y	G	Y	
Sept 2	16:10	Clear	38	E	Y	G	Y	
Sept 8	05:05	Clear		W	Y	G	Y	
Sept 12	21:37	Clear	30	W	Y	G	Y	
Sept 13	14:35	Clear	38	E	Y	G	Y	
Sept 11	21:55	Clear	33	W	Y	G	Y	
Sept 12	15:10	Clear	40	E	Y	G	Y	
Sept 14	21:20	Clear	28	W	Y	G	Y	
Sept 14	16:50	Clear	37	E	Y	G	Y	Took 3 times to punch in the # before the relay.
Sept 14	20:50	Clear	31	W	Y	G	Y	Took 2 times to punch in the # before the message relay.
Sept 15	16:15	Clear	33	E	Y	G	Y	
Sept 15	21:10	Clear	28	W	Y	G	Y	

Date 2006	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Sept 16	14:00	Clear	34	E	Y	G	Y	
Sept 17	20:18	Clear	21	W	Y	G	Y	
Sept 18	14:00	Clear	35	E	Y	G	Y	
Sept 19	20:20	Clear		W	Y	G	Y	
Sept 20	16:00	Clear		E	Y	G	Y	
Sept 21	20:10	Clear	30	W	Y	G	Y	
Sept 22	15:00	Clear		E	Y	G	Y	
Sept 21	21:45	Clear	30	W	Y	G	Y	
Sept 22	15:55	Clear	30	E	Y	G	Y	
Sept 22	20:30	Clear	30	W	Y	G	Y	
Sept 23	15:30	Rain	30	E	Y	G	Y	
Oct 2	21:30	Clear	26	W	Y	G	Y	
Oct 3	16:15	Clear	28	E	Y	G	Y	
Oct 4	20:00	Clear	28	W	Y	G	Y	
Oct 5	16:40	Clear	27	E	Y	G	Y	
Oct 8	21:35	Clear	30	W	Y	G	Y	
Oct-09	15:50	Clear	31	E	Y	G	Y	
Oct-09	20:55	Clear	27	W	Y	G	Y	
Oct-10	16:35	Clear	28	E	Y	G	Y	
Oct-10	19:55	Clear	30	W	Y	G	Y	
Oct-11	16:30	Clear	38	E	Y	G	Y	
Oct-11	20:05	Clear	30	W	Y	G	Y	

Date 2006	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Oct-12	15:00	Overcast	28	E	Y	G	Y	
Oct-13	22:25	Clear	20	W	Y	G	Y	
Oct-14	15:20	Clear	25	E	Y	G	Y	
Oct-15	22:45	Clear	30	W	Y	G	Y	
Oct-16	15:10	Clear	38	E	Y	G	Y	
Oct-16	19:50	Clear	28	W	Y	G	Y	
Oct-17	15:45	Clear	27	E	Y	G	Y	
Oct-17	19:40	Clear	30	W	Y	G	Y	
Oct-18	20:20	Rain	28	W	Y	G	Y	
Oct-18	15;55	Clear	35	E	Y	G	Y	
Oct-19	15:15	Clear	29	E	Y	G	Y	
Oct-19	20:20	Clear	30	W	Y	G	Y	
Oct-20	16:50	Rain	34	E	Y	G	Y	
Oct-23	18:40	Rain	30	E	Y	G	Y	
Oct-23	21:05	Rain	28	W	Y	G	Y	
Oct-24	14:25	Clear	28	E	Y	G	Y	
Oct-24	20:30	Clear	37	W	Y	G	Y	
Oct-25	13:35	Clear	35	E	Y	G	Y	
Oct-25	19:30	Rain	26	W	Y	G	Y	
Oct-26	15:45	Clear	27	E	Y	G	Y	
Oct-26	21:00	Clear	32	W	Y	G	Y	
Oct-27	14:15	Clear	41	E	Y	G	Y	

Date 2006	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Oct-27	21:30	Clear	22	W	Y	G	Y	
Nov-28	16:15	Clear	34	E	Y	G	Y	
Nov-29	22:34	Clear	27	W	Y	G	Y	
Nov-30	15:11	Clear	33	E	Y	G	Y	
Dec-01	21:15	Rain	24	W	Y	G	Y	
Dec-02	14:49	Clear	35	E	Y	G	Y	
Dec-03	19:50	Clear	25	W	Y	G	Y	
Dec-04	17:45	Snow	30	E	Y	G	Y	
Dec-04	18:45	Clear	22	W	Y	G	Y	
Dec-05	15:26	Clear	35	E	Y	G	Y	
Dec-05	20:25	Clear	30	W	Y	G	Y	
Dec-06	17:10	Clear	30	E	Y	G	Y	
Dec-06	21:42	Clear	23	W	Y	G	Y	
Dec-07	15:58	Clear	34	E	Y	G	Y	
Dec-07	21:00	Clear	30	W	Y	G	Y	
Dec-08	14:50	Clear	30	E	Y	G	Y	
Dec-08	20:53	Clear	24	W	Y	G	Y	
Dec-09	16:49	Clear	35	E	Y	G	Y	
Dec-11	21:38	Clear	26	W	Y	G	Y	
Dec-12	14:59	Clear	36	E	Y	G	Y	
Dec-13	21:31	Rain	23	W	Y	G	Y	
Dec-26	20:20	Rain	27	W	Y	G	Y	

Date 2006	Time	Weather (rain, fog, snow, clear?)	Speed (mph)	Travel Direction eastbound or westbound	LED correct colour? Y/N	LED visibility G = good F = fair P = poor	Correct Audio Signal Returned? Y/N	Problems / Comments
Dec-27	20:25	Clear	26	E	Y	G	Y	
Dec-28	20:40	Clear	28	W	Y	G	Y	
Dec-29	15:35	Clear	26	E	Y	G	Y	
Jan-21	20:30	Clear	25	W	Y	G	-	Forgot to ring up tower.
Jan-22	16:55	Clear	25	E	Y	G	Y	
Jan-23	20:55	Clear	28	W	Y	G	Y	
Jan-24	17:25	Clear	30	E	Y	G	Y	
Jan-25	21:05	Clear	29	W	Y	G	Y	
Jan-26	15:35	Clear	30	E	Y	G	Y	
Feb-04	0:15	Clear	25	W	Y	G	Y	
Feb-05	17:45	Clear	27	E	Y	G	Y	
Feb-06	20:30	Clear	26	W	Y	G	Y	
Feb-07	17:05	Clear	37	E	Y	G	Y	
Feb-08	21:30	Clear	28	W	Y	G	Y	
Feb-09	18:55	Clear	32	E	Y	G	Y	
Feb-10	23:50	Clear	28	W	Y	G	Y	
Feb-10	16:05	Clear	33	E	Y	G	Y	